SEISMIC DESIGN OF BRIDGES

SECTION 8

STRUCTURAL AND NON STRUCTURAL DETAILS

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8.1 GENERAL:

The following sections outline various essential design considerations for relative movement of structural members, structural integrity and repair of seismic damage.

8.2 DISPLACEMENT CONSIDERATIONS

8.2.1 Attention should be given during design to the avoidance of damage to major structural elements resulting from large relative deformations induced by strong earthquake motions.

Attention should also be given to the design of clearances around minor structural elements such as deck movement joints. At such locations strong seismic motion can be expected to cause damage. The designer should therefore detail such elements of the structure so that the damage occurs in a predictable fashion with permanent repairs being undertaken with relative ease.

8.2.2 Clearances between major structural elements and around items such as holding-down bolts designed for relative movement, may be calculated using Equation (2.3) or (2.4) of Section 2.2.2 depending on seismic zone. This equation can be used to predict the maximum seismic displacement of the centre of mass of a structural system where dynamic characteristics approximate those of a single degree-of-freedom oscillator.

In cases where the structure cannot be adequately modelled as a single degree-of-freedom oscillator, it may be necessary to resort to the use of more refined analytical techniques in order to realistically assess relative displacements under seismic loading.

8.2.3 In structures of low displacement ductility or in cases where the evaluation of relative displacement is uncertain, it may be necessary to use elastomeric buffers to reduce possible impact forces which may occur between major structural elements during strong earthquake motions. In addition, adequate clearances should be left to ensure that large forces will not develop during more frequently expected moderate earthquakes.

8.2.4 At points such as deck movement joints, clearances in the joint and its immediate supports after making allowances for long term shrinkage and creep movements, should be at least 0.15 and preferably 0.25 times the relative movement calculated using Equation (2.3) or (2.4) of Section 2.2.2.

8.3 STRUCTURAL INTEGRITY

8.3.1 Positive longitudinal linkage should be provided between adjacent sections of superstructure at supports and hinges and between superstructures and their pier supports.

At abutments positive horizontal linkage between the superstructure and the abutment should also be provided unless the minimum overlap distances between superstructure and substructure as defined in figure 8.1 are satisfied.

Details of a variety of linkage systems are given in figure 8.2. If the linkage is at a point where relative deflection between the sections of superstructure or between superstructure and substructure is intended to occur during seismic motions, sufficient slack should be left in the linkage so that it does not start to act until the design seismic deflection is exceeded.

8.3.2 Holding-down devices should be provided at all supports or hinges in continuous structures where the upwards vertical reaction generated by a horizontal or vertical seismic load opposes and exceeds 50% of the static dead load reaction.

In calculating the appropriate upwards seismic design reaction at any support or hinge, the horizontal seismic force should be that required to form a plastic mechanism, assuming all plastic hinges have developed their overstrength capacity. In all cases the minimum design strength for the holding-down device should be 20% of the dead load downwards force which would be exerted if the span was simply supported, or where the net residual load is negative (dead load minus upwards seismic reaction) use twice the value of that load, whichever is the greater.

8.4 REPAIR CONSIDERATIONS

8.4.1 The designer should consider the likely method of repair and ease of access to areas of a structure where seismic damage will most probably be sustained.

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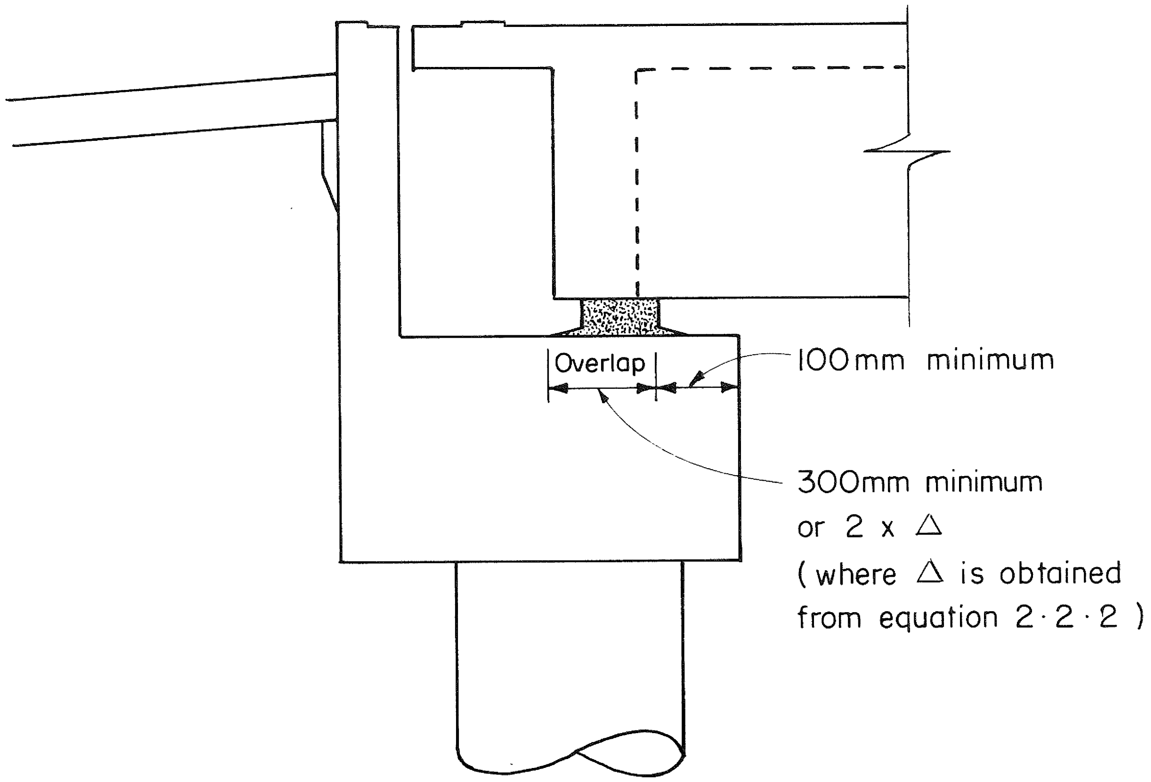
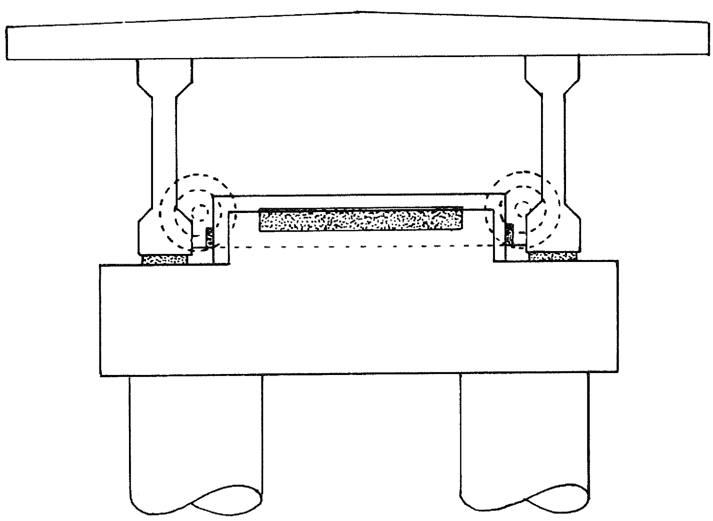


FIG. 8·1 OVERLAP DISTANCE



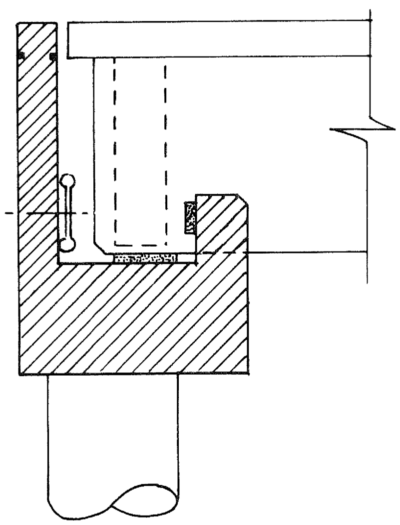


FIG. 8·2 ALTERNATIVE ABUTMENT LINKAGE

8.4.2 The designer should consider the hierarchy of inelastic failure of structural members during strong earthquake motions. It is recommended that members which are expected to fail first during severe seismic shaking should be the easiest to repair both temporarily and permanently.

COMMENTARY SECTION 8:

C8.1 This section of work confines its recommendations to detailing for displacement rather than for strength requirements which are covered elsewhere.

In order to speed up design methods and make structures more economical, the MWD[C8.1] have developed standard seismic details for bridges which utilise their simple supported standard pre-cast beams. The detailing concepts incorporated in these standard designs are nevertheless applicable to the design of more complex structures.

C8.2.2 The clearance requirements described in this section are generally only minimum values. The designer should consider that clearances might also be required (say between abutment backwalls and the end diaphragms) for access for maintenance and/or repair of seismic hardware. MWD standards contain recommendations on clearance for particular structural layouts.

C8.2.4 Because actual movements are likely to exceed those for which the deck joints are designed it is accepted that damage caused by strong earthquake motions may occur in parts that are not main structural members. As a result a plane of weakness should be introduced to allow secondary damage to occur in a predetermined and limited manner, in order to permit early use of the bridge after a major earthquake. Judgement should be exercised in determining the amount of long-term shortening which is to be combined with earthquake movement in deriving the design value for joint displacement. Elastomeric bearings which transfer significant seismic forces from the superstructure to the substructure should be positively anchored to their supports with dowels or equivalent.

This system of anchorage is particularly desirable where bearings could possibly slide and fall off the bearing seats under seismic action.

Elastomeric bearings should be designed to meet the general requirements of the DoE Technical Memorandum No. B E 1/76[C8.1]. This document however, does not specifically mention allowances to be made in the design of a bearing under seismic loading. Dynamic tests[C8.2] have shown that elastomeric bearings are able to sustain several cycles of loading reaching shear strains of 130% without appearing to suffer catastrophic damage.

It is expected however, that strains of such a magnitude would tend to move the bearings on their seats (if slipping is permitted) or in the case of prolonged cyclic excursions to strains in the order of 130%, bearings would probably need to be replaced.

It is recommended that elastromeric bearings should be designed to have maximum permissible shear strains of 100% under full design seismic load.

Expansion joints at supports, which provide significant seismic restraints to the superstructure should be designed to fail in such a manner that minimum permanent damage is caused to the expansion joint itself. MWD standard details[C8.3] show expansion joints attached to cantilever slabs which hinge up under severe earthquake loading. Alternatively at abutments the expansion joint may be attached to a deck slab which impinges upon the top of the abutment backwall which in turn is designed to be knocked off under severe earthquake loading.

It is considered that the knock-up cantilever slab shows most promise at this stage.

The designer should consider the use of expansion joints which can be supported in such a way that the structural steel components of the joint will receive little or no damage severe seismic shaking, eg. compression seals or strip seals.

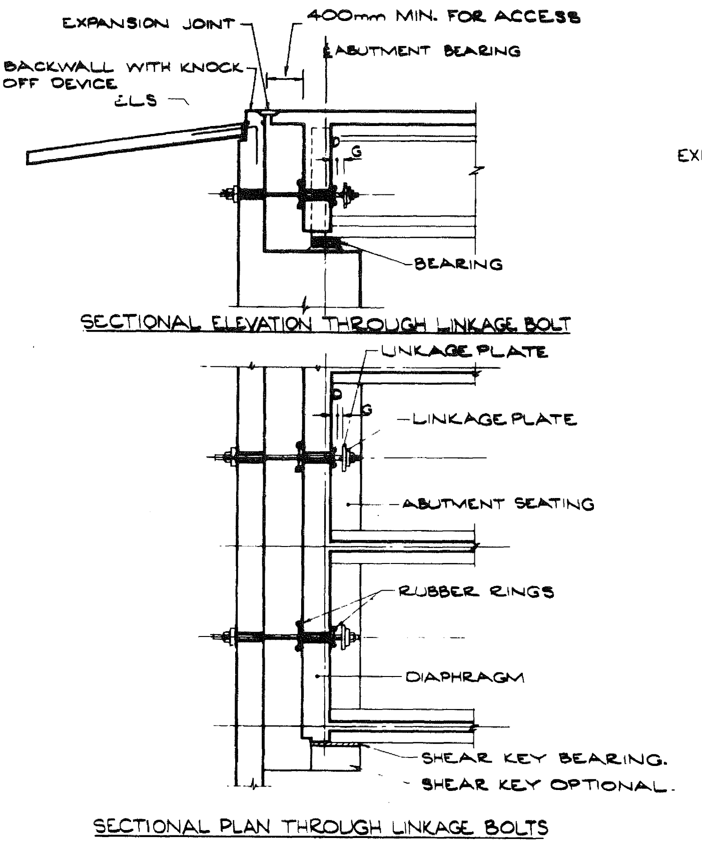
C8.3.1 Structural integrity can only be maintained if extreme displacements are controlled to prevent any span elements dropping from their supports.

Where possible, the superstructure should be designed to be continuous or linked together at pier supports with a hinged linkage slab (normally as part of the deck) to cause the deck to act as a longitudinal diaphragm under transverse seismic action but with no significant influence on live load moment. This diaphragm action can then be used to maintain structural integrity and enable the rational distribution of transverse seismic forces between supporting piers and/or abutments.

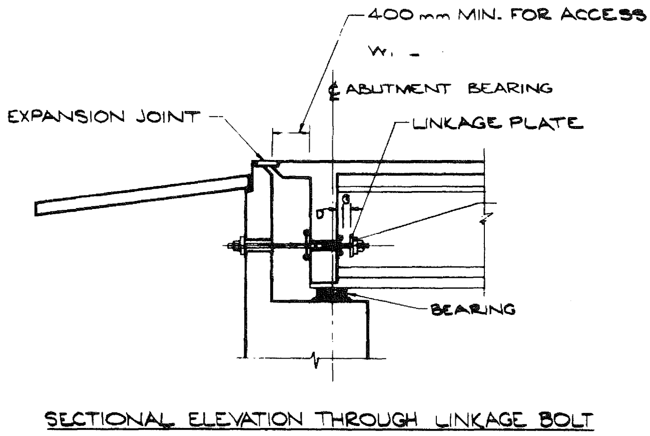
Figure 8.3 gives some details of standard MWD[C8.3] seismic linkage hardware, eg. linkage bolts and their associated buffer rings. Alternative reinforced concrete shear key arrangements at abutments and piers are also shown.

The provisions for calculation for design loads in these linkage elements are at this stage rather empirical in nature. It is recommended however that the design strength of the linkage element should have a minimum value of 0.2 x the weight of the heavier of the two adjoining spans or parts of the structure, or such a value as may be determined by a rational analysis which takes account of the dynamic interaction of the superstructure and support elements.

C8.3.2 This section attempts to give the designer some guidance about the design of holding down bolts in continuous structures.



TYPICAL ABUTMENT LINKAGE

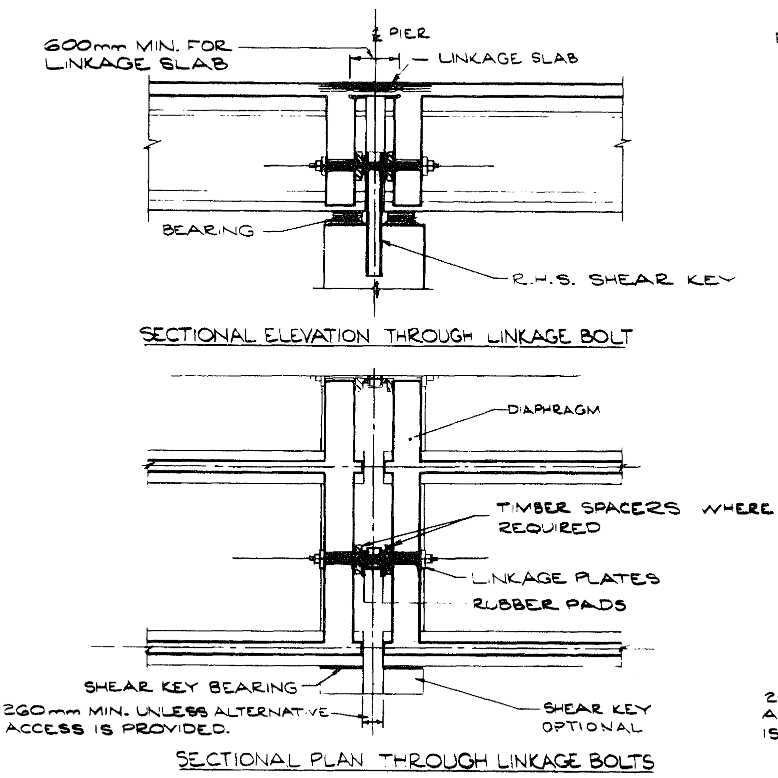


ALTERNATIVE ABUTMENT LINKAGE

(ALTERNATIVE WITH DECK CANTILEVER DESIGNED TO HINGE UPWARDS.)

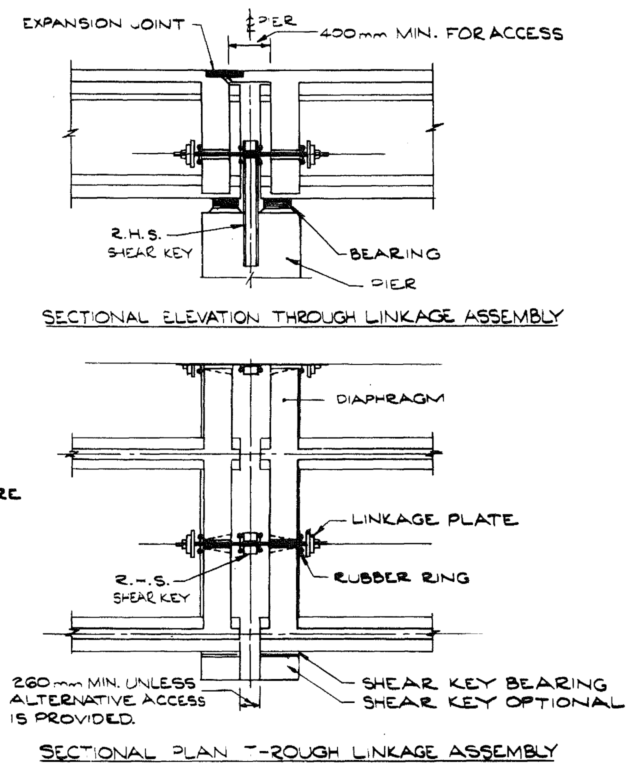
FIG. 8 · 2

TYPICAL DETAILS OF SEISMIC CONNECTIONS AT PIERS AND ABUTMENTS



TYPICAL PIER CONNECTION

(With deck linkage)



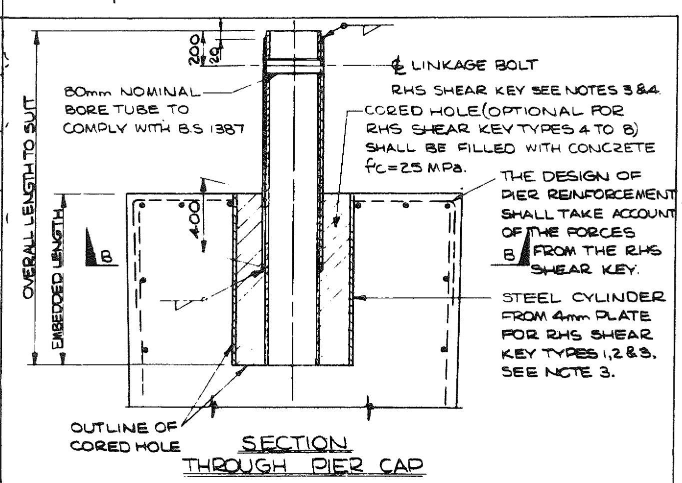
TYPICAL PIER CONNECTION

(With deck expansion joint)

FIG. 8 · 2

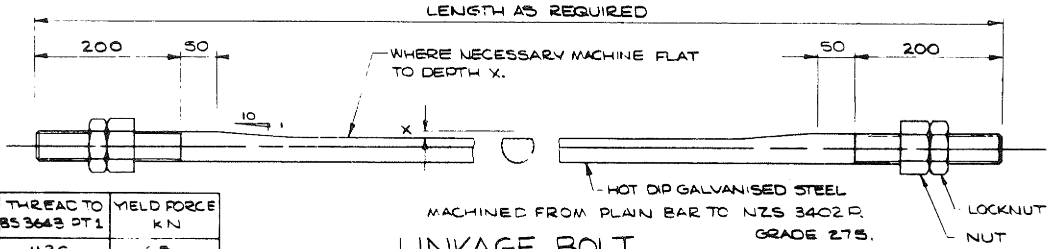
TYPE		SIZE A × B × C	MASS [kg/m]	M_E [kN.m]	V_{sy} [kN]	EMBEDDED LENGTH [m]
	1	304.8 × 304.8 × 16.0 + 2 PLATES 360×20 (15mm CONTINUOUS FILLET WELDS)	256	986	1368	0.9
	2	304.8 × 304.8 × 16.0 + 2 PLATES 360×10 (12mm CONTINUOUS FILLET WELDS)	200	677	1368	0.8
	3	304.8 × 304.8 × 16.0	145	422	1368	0.7
	4	406.4 × 203.2 × 16.0	143	314	912	0.8
	5	406.4 × 203.2 × 12.5	116	262	712	0.7
	6	406.4 × 203.2 × 9.5	88	206	541	0.6
	7	304.8 × 203.2 × 9.5	73	160	541	0.6
	8	304.8 × 203.2 × 6.3	49	112	359	0.5

f_{sy} = STRESS AT FIRST YIELD, ASSUME f_{sy} = 255 MPa.
V_{sy} = SHEAR STRESS, ASSUME V_{sy} = 0.55 × f_{sy}.
M_E = ELASTIC LIMIT MOMENT CAPACITY OF RHS SHEAR KEY ABOUT AXIS X–X AT f_{sy}.
V_{sy} = SHEAR CAPACITY OF RHS SHEAR KEY AT RIGHT ANGLES TO AXIS X–X



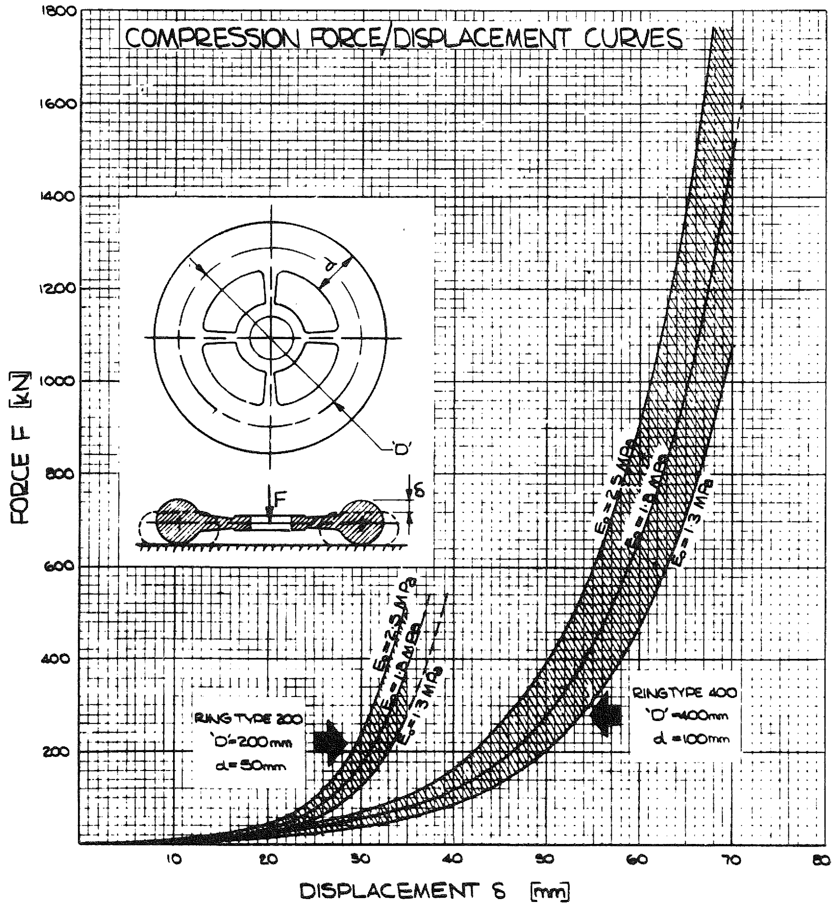
SECTION THROUGH PIER CAP

R.H.S SHEAR KEYS



BOLT DIA [mm]	BAR DESIGNATION	X mm	THREAD TO BS 3643 PT 1	YIELD FORCE kN
20	R 20	MACHINING NOT REQD	M20	65
32	R 32	6.6	M32 × 2	190
40	R 40	9.2	M40 × 3	280

LINKAGE BOLT



RUBBER RING BUFFERS

FIG. 8·3

SEISMIC HARDWARE

In determining whether or not hold downs are required (refer first paragraph of Section 8.3.2) the horizontal load may be determined from Equation (2.1) of Section 2.1.1. In looking at the reactions caused by vertical seismic accelerations the designer is referred to Sections 2.3, C2.3.2 and C2.3.3 for methods of determining the magnitude of these reactions.

The recommendations contained in Section 8.3.2 are rather empirical in nature as they contain complex loadings, ie. vertical reactions induced by horizontal earthquake action, or alternatively, vertical reactions from vertical earthquake action.

It is recommended however that the designer need not consider the concurrent effects of vertical and horizontal seismic accelerations when designing holding-down bolts.

The designer is urged to exercise broad judgement in determining the size and location of hold-down bolts. In many instances it is considered that the overall capacity of the hold-down bolts should be at least twice that required by Section 8.3.2 where it may be extremely difficult to replace such items in the event that they fail under earthquake loading.

The designer should be aware that in the unlikely event that a simply supported span is subjected to an upwards seismic acceleration only, then theoretically the hold-down bolts would not be required unless the upwards acceleration exceeded gravity.

C8.4.1 This section refers for example, to pier cap and abutment widths in cases where the bearings might need replacement after sustaining severe seismic shaking. Sufficient clearance should be provided to enable standard jacking equipment to be used.

In regard to repair of plastic hinge areas on piers for example, it may be judicious to provide suitable locating fixtures (or holes in the piers) from which scaffolding could be suspended for repair work.

C8.4.2 This section aims at making the designer aware of the need to consider in detail the mode of failure of the structure in the event of strong seismic motion.

Consider for example the likely seismic damage that could be incurred at an abutment with the following characteristics:

*Expansion joint at deck

*Linkage bolts through abutment backwall and diaphragm between beams

*Elastomeric bearings

*Piles designed to take longitudinal and transverse loading

It is suggested that it is easier to repair properly detailed expansion joints, linkage bolts and bearings, than it is to repair the abutment backwalls, diaphragms or piles. In detailing the various component members of this abutment, the designer should therefore provide clearances and member strengths which ensure that the piles and backwall are the least likely to sustain permanent damage.

C8.5 <u>REFERENCES</u>:

C8.1 Department of the Environment, "Design Requirements for Elastomeric Bridge Bearings", DoE, Highways Directorate (Gt. Britain), Technical Memorandum (Bridges) No. B E 1/76, February 1976.

C8.2 Tyler, R.G. - "Dynamic Tests on Laminated Rubber Bearings", Bulletin of the NZ National Society for Earthquake Engineering, Volume 10, No 3, September 1977.

C8.3 Ministry of Works and Development, "Standard Plans for Highway Bridge Components", MWD, Civil Division Publication, CDP/901, Wellington, New Zealand, January 1978.